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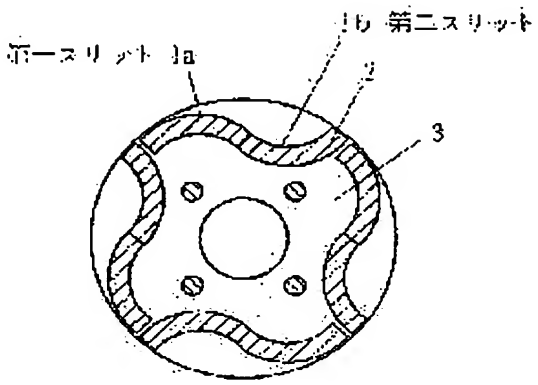
(71)Applicant : AICHI EMERSON ELECTRIC CO LTD
(72)Inventor : TAKAHASHI TOMOFUMI

(54) ROTOR STRUCTURE FOR BRUSHLESS DC MOTOR

(57)Abstract:
PROBLEM TO BE SOLVED: To realize a brushless DC motor, whose torque characteristic can be set arbitrarily and whose drive control is easy.
SOLUTION: In this brushless DC motor, slits are executed inside a core for a rotor, magnets are arranged at the slits, and field poles are formed. A first slit and a second slit are formed inside the core which forms identical field poles at the rotor. The first slit has a curvature which is larger than that of the outer circumference of the stator, and it is curved into an arc shape along the outer circumference of the rotor. The first slit is situated to the outer circumference of the rotor on the side between poles on one side of the field poles, and it is situated to the inner circumference of the rotor on the side of the center line of the field poles. In addition, the second slit is curved arcuately in reverse to the outer circumference of the rotor. The second slit is situated to the inner circumference of the rotor on the side of the center line of the field poles, and it is executed so as to be the outer circumference of the rotor on the side of poles on the other side of the field poles, so that the first slit and the second slit merge between the poles, and the magnets are arranged inside the slits.



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CLAIMS

[Claim(s)]
[Claim 1] In the brushless motor which a slit is given to Rota incore, arranges a magnet on this slit, and forms the field pole It has the first slit and the second slit in incore [which accomplishes the same field pole of this Rota]. The first slit has large curvature, and along with the periphery of Rota, incurvate it in the shape of radii, and it consists of the periphery of Rota. And said first slit is the Rota periphery approach in one between [poles] side of the field pole. Are given so that it may become the Rota inner circumference approach by the center line side of the field pole, and the second slit incurvates the periphery of Rota in the shape of radii conversely, and changes. And said second slit is the Rota inner circumference approach in the center line side of the field pole concerned. Rota structure of the brushless DC motor characterized by being given so that it may become the Rota periphery approach by the between [poles] side of another side of the field pole concerned, making it said first slit and second slit join in between the poles concerned, and arranging a magnet in this slit.
[Claim 2] Rota structure of the brushless DC motor given in the 1st term characterized by said first slit and second slit being the same curvature.
[Claim 3] Rota structure of the brushless DC motor given in the 1st term which enlarges the curvature of the first slit in enlarging the rate of reluctance torque to the magnet torque as a motor, and is characterized by it having been small in the curvature of the second slit, having made the curvature of the first slit small when the rate of reluctance torque to said magnet torque was conversely made small, and enlarging the curvature of the second slit.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention gives a slit to the core of Rota of a brushless DC motor, gives the phase contrast of arbitration to the magnetic shaft about reluctance torque, and the magnetic shaft about magnet torque about Rota which arranges a magnet on this slit and grows into it, and relates to the structure where a reluctance torque component and a magnet torque component can be set as arbitration.
[0002]
[Description of the Prior Art] A slit is given in Rota, and what arranges a magnet on this is usually called magnet embedding mold Rota, and is used in the large field. [many] An example of the Rota structure in the conventional brushless DC motor is shown in drawing 6 and drawing 7 . A magnet is arranged on the slit given so that drawing 6 might make reverse radii to the periphery of Rota. In drawing 6 , a slit 1, a magnet 2, and the rotor core 3 are shown. On every pole in Rota, periphery surface magnetic flux is homogeneity mostly. The thing of radial orientation is magnetically used in the direction of the diameter of Rota, and the magnet 2 has the radii central point and an orientation focus on the center line of the field pole. Reluctance torque is made to act in addition to the usual magnet torque, and it enables it to raise the torque of a motor by this type with the rotor core 3 which is magnetic material thick in the direction of the diameter of Rota which intervenes between a magnet 2 and the Rota front face.
[0003] This reluctance torque has about 90 degrees of phase reference electrically to magnet torque, and changes with torque twice the period of a magnet. Since the direction of the path of the core which is the magnetism material which intervenes the more between a magnet 2 and the Rota front face the more the location where a magnet 2 is arranged is on the bore side of Rota, namely, the more it is going to use reluctance torque for an effective target the more more as a motor becomes long, distribution of magnetic flux becomes easy, and the magnet magnetic-flux distribution on the front face of Rota further becomes easy to grow into homogeneity.
[0004] An example shows the flow of the magnetic flux which signs that the magnetic flux which a magnet 2 emits distributes, and reluctance torque generate to drawing 7 . The same notation as drawing 6 shows the same object with the notation of drawing 7 , and phim shows the flow of magnetic flux when external excitation is performed, when magnet magnetic flux and phir acquire reluctance torque. A field pole core takes the lead in magnet magnetic flux, d shaft is usually set as this, and to d shaft, the location between the field poles is 90-degree phase contrast electrically, and is setting q shaft as this. In this drawing, although the open angle of a field is theta 1, it is the relation of a configuration of coming from arrangement of a slit 1, the effective field fields for the include angle which is equivalent to the width of face of a slit 1 between the field poles decrease in number, and an effective field open angle becomes theta 2.
[0005] That is, since the orientation of the magnet 2 arranged on this slit 1 is on the direction side of a radii core of a slit 1, the magnetic flux from a magnet 2 serves as a tangential direction with the Rota periphery in field pole Mabe, and it will not be suitable in the effective direction of a path as the field pole of a rotator. Therefore, the both ends of a slit 1 are no longer an effective field as the field pole. The magnetic core of the field pole is in agreement with the center position on the geometry of structure so that drawing 7 may also show. That is, since the configuration of a slit 1 and arrangement are made into bilateral symmetry to the field pole center position concerned and the uniform magnet 2 is arranged on this slit 1, magnetic-flux distribution in the Rota periphery section of this field pole serves as bilateral symmetry like structure. Moreover, the core of a field that reluctance torque acts is also in agreement with the center position of the field pole. Here, it is combined with such Rota and the stator of a three-phase motor and the opposite part of Rota which are constituted are shown in drawing 8 .

[0006] This drawing is developed and illustrated to a circumferencial direction in the field where a stator counters with Rota. In drawing 8 , the same notation as drawing 6 shows the same object, thetad can show the invalid field include angle of the field pole which exists between the field poles shown in drawing 7 , and the relation with drawing 8 can be expressed like the following type (1).
theta d=theta 1-theta2 (1)
A stator 4 shows the thing of 12 slots usually used well. S1-S12 show the slot number of a stator 4, and in this example, since they are 12 slots, they return to a list S1 in order to S12. It is given to this slot so that the phase winding of U-V-W may serve as 4 pole configurations by the abbreviation volume.
[0007] In drawing 8 , if Rota shall rotate by the RRC, the magnetic flux of the magnet 2 which flows from Rota 3 to a stator 4 will move to the right from the left. The timing of the energization current Is to a phase winding required in order to make it operate as the induced voltage E and the motor which are generated in the amount phi of magnetic flux interlinked to the phase winding of the arbitration at this time and the phase winding concerned is shown in drawing 9 . Change of the amount phi of magnetic flux which Rota interlinks to each phase winding in the condition of rotating by fixed **, now serves as a wave if the condition of illustration is made into a time amount origin (t0), for example it will see about U phase winding, as shown in the upper case of drawing 9 , and the induced voltage E generated by change of the magnetic flux interlinked to these U phase windings at this time serves as a wave shown in the middle of drawing 9 . It is an electrical angle used as the induced voltage of low level until electrical angle thetas is a part equivalent to invalid field include-angle thetad of the field pole in drawing 8 , this invalid field part starts opposite to the phase winding concerned and all finish opposite in the induced voltage E of the middle, or until [since it begins to slip out of opposite of the phase winding concerned conversely,] it finishes escaping.
[0008] In this section, there is extremely little change of the amount of magnetic flux interlinked since the about 0 magnetic-flux field is only moving until the invalid field of the field pole which counters the phase winding concerned starts and finishes passage, therefore there is extremely little generating of induced voltage. The relation between invalid field include-angle thetad and low induced voltage electrical angle thetas becomes like P, then the following type (2) about the pole of the field pole of Rota.
theta s=Pxtheta d/2 (2)
since the field pole of Rota is bilateral symmetry also magnetically and geometrically on the basis of a field pole center line in drawing 7 , even if magnetic flux moves [Rota] to the left from the right by the RLC -- drawing 9 -- the induced voltage E of the middle does not change.
[0009] Usually, the motor concerned can be operated if the 120-degree drive current Is is passed like the drawing 9 lower berth in an electrical angle according to such timing of an induced voltage wave. Of course, although energization of 180 degrees of electrical angles could also be operated by the same phase relation, in this explanation, it illustrated about the case of 120-degree energization. Now, as shown in drawing 8 , when a motor is constituted combining a stator, If it considers as 2 phase machine equivalent to the three-phase-circuit machine expressed by the rotational coordinates rotated synchronizing with rotation of Rota which showed the three-phase-circuit machine in a fixed coordinate to drawing 7 and the axis of coordinates of criteria is set as d shaft and q shaft in drawing 7 The formula of the torque of this motor is T=Pnx {phiaxIaxcosbeta+(Lq-Ld) xIa2xsin2beta}. (3)
Being ** carried out is just going to be known well.
[0010] The actual value of the flux linkage to the excitation winding as a 2 phase machine according [Pn] to a magnet at the number of pole pairs here according [T] in 1/2 of a pole P, and phia to comprehensive torque, the equivalence inductance of stator winding in d shaft and q shaft when Ld and Lq transpose a three phase machine to equivalent 2 phase machine, respectively, and Ia -- the above-mentioned -- the magnitude of the excitation current phasor in equivalent 2 phase machine and beta express the phase from q shaft of this excitation current phasor. The 1st term of the above-mentioned (3) formula is expressing the so-called magnet torque by the magnet and the exciting current Ia, and the 2nd term is expressing reluctance torque. Reluctance torque has the twice as many change period as this to the change period of magnet torque acting in union corresponding to the excitation current phasor phase beta so that more clearly than a formula.
[0011] Moreover, the sign is given to the term of magnet torque at the term of cosine and reluctance torque, and each term of this formula shows mutually that phases differ at least in 90 degrees only of electrical angles. Therefore, phase contrast beta of the excitation current phasor by which magnet torque and reluctance torque are compounded in the same direction is realized by the electrical angle whenever [0 degree < beta< 90 degrees angle-of-lead], and when it deviates from this range, it will act in the direction which mutual torque negates mutually. (3) If a formula is expressed by a diagram, it will become like

drawing 10 . The inside Tm of drawing expresses the comprehensive torque by which (3) type expressions whose T magnet torque and Tr compounded reluctance torque and compounded the magnet torque Tm and the reluctance torque Tr are carried out.
[0012]
[Problem(s) to be Solved by the Invention] In this kind of motor, its best was conventionally done as like [it is high and] in the motor engine performance by raising the torque constant as a motor. For example, the device which considers effectively as use the reluctance torque which gives the radii slit 1 contrary to a periphery to the rotor core 3 like drawing 6 , passes through the inside of the magnetic material to which the magnetic flux produced in the energization to the coil of the stator which arranges a magnet 2 on this slit 1, and counters it intervenes between the Rota periphery and a magnet, and is brought about utterly is also one of them, and, as it is, is raising effectiveness like the comprehensive torque T which described as a conventional example.
[0013] However, as magnet torque and reluctance torque were shown in (3) types or drawing 10 The field which will strengthen each other if each torque is compounded depending on the energization phase of the exciting current over the location of Rota, and the field to weaken exist. Magnet torque and reluctance torque suit in slight strength mutually by the case where it is the progress whose current phase from q shaft is 0 degree - 90 degrees, and, in the case of the delay phase which is 0 degree - -90 degrees, magnet torque and reluctance torque are weakened mutually. this thing is the process which is put in another way and which current energization to the phase winding of a certain arbitration is performed, and Rota rotates in the usual motor operation if it becomes, and since the exciting-current phase seen from q shaft of this Rota progresses, it is exactly moving in the direction of delay.
[0014] For example, even if it progresses an exciting-current phase to q shaft and starts energization at 90 degrees, motor torque will change with rotations of Rota like the comprehensive torque T of drawing 10 toward the direction of a delay phase gradually. If energization is performed over 180 degrees, after going into the field of a delay phase, torque decreases quickly. Moreover, even if 120-degree energization which this kind of motor may be used for, and is used as well as the above progresses an exciting-current phase and it starts energization at 90 degrees, even 0 degree - 30 degrees even of delay phase fields will exist, and the large reduction field of comprehensive torque will remain. That is, pulsation of big torque is not avoided by the rotation location of Rota. Moreover, as it is shown in drawing 6 **** drawing 9 and explanation was added, the slit of radii will be given to hard flow to the periphery of Rota, and a field with very little generating of the induced voltage which an effective field pole field decreases to this slit with the structure which carried out magnet **, and thetas Becomes as a result will be produced. Therefore, about magnet torque, even if it energizes a current to a phase winding in this field, generating of torque is not expectable. Although drawing 9 showed the case of 120-degree energization which can avoid energization in thetas field, in 180-degree energization, the useless current for theta s minutes will be passed in one period, and aggravation of effectiveness will not be avoided, but an energization field will reach a field with little induced voltage of a motor by slight gap of the timing of energization also in 120-degree energization, and generating of motor torque will change a lot. Although effectiveness was accepted with the conventional Rota structure like the above if attached to partial raising of torque, it was not taken into consideration about the sound or vibration accompanying torque pulsation or it.
[0015]
[Means for Solving the Problem] It is that to which curvature is large and the first slit curves from the periphery of Rota along with the periphery of Rota to incore [which accomplishes the same field pole of Rota] in the shape of radii. And arrangement is the Rota periphery approach in one between [the field poles] side of Rota, and it is given so that it may become the Rota inner circumference approach by the field pole core side. The second slit curves in the shape of [contrary to the Rota periphery] radii, and it is given, and the second slit is the Rota inner circumference approach in the center line side of the field pole concerned. Are given so that it may become the Rota periphery approach by the between [poles] side of another side of the field pole concerned, and it is made for the first slit and the second slit to join in between the poles concerned, and the magnet was arranged on this slit.
[0016]
[Embodiment of the Invention] The suitable example of this invention is shown in drawing 1 , and it explains to it. Drawing 1 shows Rota in case the field poles are four poles, and has illustrated it about the field pole of a pair. The notation attached in drawing 1 shows first slit 1a, second slit 1b, a magnet 2, and the rotor core 3, and the magnet 2 is arranged on each first slit 1a and second slit 1b. First slit 1a curves in the same direction as the periphery of Rota, and curvature is greatly set up from the periphery of Rota. The one

side edge of first slit 1a is in a between [the field poles] side, and the periphery of Rota is made to have approached, and the other end is located in the core side of the field pole concerned. Since this slit has curvature larger than the periphery of Rota, on the other hand, the other end will be inevitably located in the inner circumference of Rota from an edge. Second slot 1b allots the one side edge to the between [the field poles] side of the opposite side the between [the field poles] side when first slit 1a of the field pole field concerned was given, it is made to curve to the periphery and hard flow in Rota, and the other end of this slit is given so that the other end of first slit 1a may be joined. Therefore, first slit 1a and second slot 1b become one slit which surges like a wave within the same field pole as a result.

[0017] Next, the core of a magnetic shaft is explained using drawing 2 . Drawing 2 is a thing illustrating one of the four field poles, the structural field pole medial axis J1 of the example of this Fig. is shown at an angle of theta 3 from one ****** X of the field pole concerned, and a machine angle is 45 degrees in this phase. Moreover, one effective field pole field in Rota is the section of thetak shown in drawing 2 . That is, since the effective field pole is between the field poles mostly since the first slit 1a end face between the field poles faces ******, and a slit end face faces the periphery side of Rota between the field poles of second slit 1b, the effective field pole decreases by the include angle equivalent to the thickness of a slit, and an effective field pole include angle turns into an include angle shown by thetak in a result and the field pole concerned.

[0018] Especially about the magnetic medial axis as the field pole, when the orientation of the magnet 2 arranged on a slit is a radial, since the orientation focus of the magnet 2 of second slit 1b is on the Rota periphery side when based on a magnet 2, the magnetic flux in this part increases. Therefore, the magnet 2 of second slit 1b approaches an X-axis side at the appearance shown in the field MAG medial axis J2 of drawing 2 , and the include angle from the X-axis is set to theta 4. This means that the shaft moves to a side with much magnetic material relatively [the magnetic core about magnetic flux with a magnet 2] between the Rota periphery and a slit.

[0019] Furthermore, the reluctance medial axis of a field which generates the reluctance torque which makes a magnetic path the magnetic material which intervenes between the slit of Rota and a periphery The field where reluctance torque acts effectively Since it is restricted to the field which corresponds mostly between second slit 1b given so that the magnetic path cross section in Rota might serve as reverse radii to the radii of the Rota periphery which becomes large On structure, inevitably, effective field magnetic pole field thetak of a magnet 2 becomes narrow, and becomes the location of the include angle theta 5 from the X-axis as a result like the reluctance medial axis J3 which serves as X-axis approach from the include angle theta 4 of the field MAG medial axis J2 further, and is shown in drawing 2 .

[0020] Therefore, a desired difference can be given to a reluctance medial axis and a field magnetic pole medial axis by setting up radii curvature and a radii length ratio suitably in first slit 1a and second slit 1b. Moreover, in one side, if the curvature of this first slit 1a becomes large, it is clear that the field which breadth reluctance torque generates [the field where the direction thickness of the diameter of Rota of the magnetic material which intervenes between a slit and the Rota periphery is large] in a circumferencial direction spreads, and the area size which acts effectively [reluctance torque] can adjust also with the curvature of a slit. If the difference (theta3-theta4) of the difference (theta3-theta5) of a field pole medial axis and a reluctance medial axis, a field pole medial axis, and a field MAG medial axis is applied and considered as a difference of each shaft from a field pole medial axis at an above-mentioned ceremony (3), the torque as a motor when such will become like (4) types, when it considers as the number Pn of pole pairs of the field pole.

T1=Pnx [phiaxIaxcos{beta+Pnx(theta3-theta4)}+(Lq-Ld) xIa2xsin{2 beta+Pn x(theta3-theta5)}] (4)

here -- < (theta3-theta4) (theta3-theta5) -- it is . this -- the comparison of (3) types and (4) types -- setting -- [] in (4) types -- it is shown to the movement magnitude of the phase of the 1st term about the magnet torque described inside that the movement magnitude of the phase of the 2nd term about reluctance torque becomes large. Therefore, since the 1st term is a cosine function and the 2nd term is a sine function, originally the 1st term and the 2nd term over the same current phase have 90-degree phase contrast, and from the 1st term, since the upper 2nd term shifts in the direction which becomes large, as for the phase contrast of magnet torque and reluctance torque, it will spread [phase contrast].

[0021] Since it is restricted to the field in which reluctance torque is mostly equivalent to the section of second slit 1b when the field which acts effectively becomes large [the magnetic path cross section in Rota] in this invention, if this including (4) types is expressed by a diagram, it will become like drawing 5 . (3) Moving in the electrical degree part progress direction in which the peak of magnet torque is expressed with the value of Pnx (theta3-theta4) in the motor by the Rota structure of this invention, as it indicates (4)

types and drawing 5 that it is clear as compared with a formula and drawing 10 , the peak of reluctance torque moves to the location of the electrical degree of Pnx (theta3-theta5) which turns into whenever [angle-of-lead] further. As compared with the comprehensive torque T of drawing 10 , the comprehensive torque which compounded both becomes like T of this drawing 5 , and is [the width of face of the field near peak torque is wide, and] moderate. [of change] For example, if a high torque condition is stably maintainable in 60-degree section which is one energization pattern if it is the drive method of 120-degree energization, it can consider as a motor with little torque pulsation. Therefore, it is shown that the comprehensive torque T in the case of drawing 5 becomes a motor with very little pulsation.

[0022] Next, relation with the stator which develops Rota of drawing 1 to a circumferencial direction, and counters is shown in drawing 3 . The part of a stator is the same as drawing 8 . Effective field pole include-angle thetak of the field pole explained by drawing 2 has come to be large by the include angle which is equivalent to the thickness of a magnet 2 compared with theta 2 in above-mentioned drawing 7 . Therefore, invalid field magnetic pole include-angle thetam is thetam**thetad/2. (5)

The conventional invalid part becomes Mr. ** in one half. It reduces even to the width of face with which, as for the amount of magnetic flux which the relation of the amount of flux linkages shown by drawing 9 , induced voltage, and the phase current which should be energized becomes like drawing 4 by this thing, and is interlinked to a phase winding, the section of change spreads, and the electrical angle section when the induced voltage of low level appears is indicated to be by thetat.

[0023]

[Effect of the Invention] If it depends on this invention, it can constitute so that the first slit may be made into the periphery of Rota, and the radii of this direction, the second slit may be made into hard flow radii with a field pole center line as the starting point about the slit on which a magnet is arranged and both may continue, and a difference can be prepared in a field magnetic pole core and a reluctance medial axis with a magnet by having arranged the magnet on this slit. Therefore, the comprehensive torque which changes into the condition of arbitration and is made into the purpose can be acquired by performing suitably the phase of the magnet torque as a motor, the phase of reluctance torque, the curvature of the above-mentioned slit, and the radii length ratio of a slit. It is possible to use properly by this like the motor which thought magnitude as important about torque, and the motor which thought pulsation as important.

[0024] Moreover, when the first slit and the second slit are the same configurations, the magnet arranged on this slit is the same, and can constitute. This means that mean consisting of single magnets like conventional Rota, and it can realize by Rota of this invention not increasing the class of component part, and carrying out it. Moreover, the same effectiveness can also be acquired by not dividing a magnet as the first slit and the second slit, but really constituting from an object. the time of constituting a motor in one side, since the invalid field of the field pole reduced by half mostly the slit configuration of this invention, and arrangement of a magnet compared with the configuration conventionally -- the above-mentioned -- the electrical-machinery angle section when the induced voltage of low level appears becomes small, and the Rota location detection precision of the control unit which is going to drive this motor by this using the induced voltage generated in the coil of a motor becomes good. Therefore, while it is possible for it to be efficient and to make a motor operate, the big effectiveness of being stabilized even if it changes the timing of the energization to the location of Rota, and continuing a drive can be acquired.

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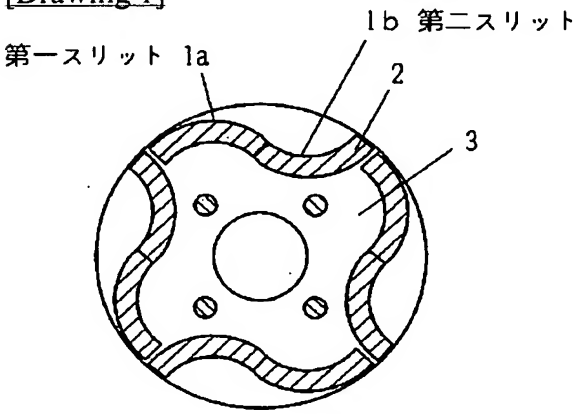
DRAWINGS

[Drawing 1]



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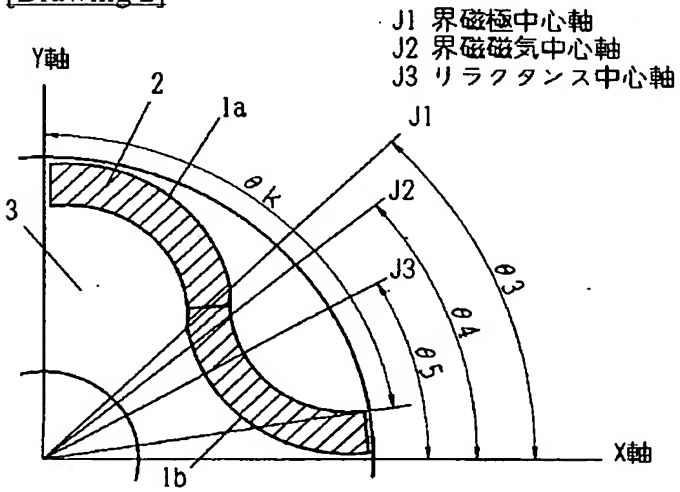

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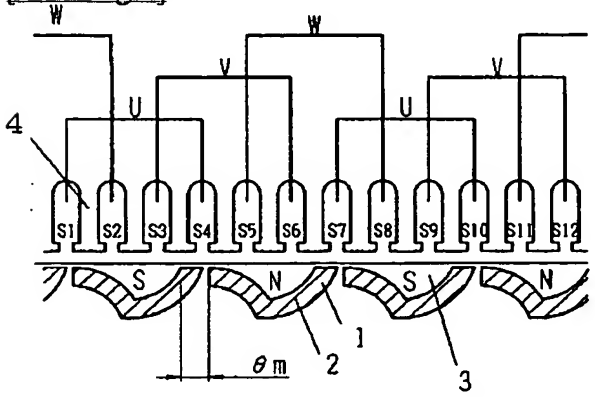

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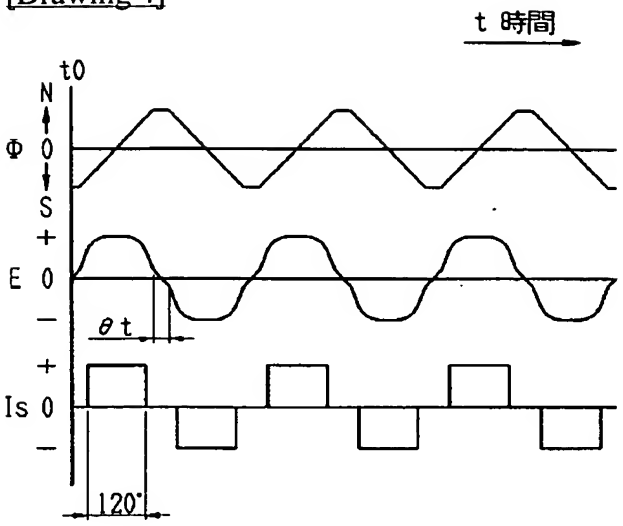

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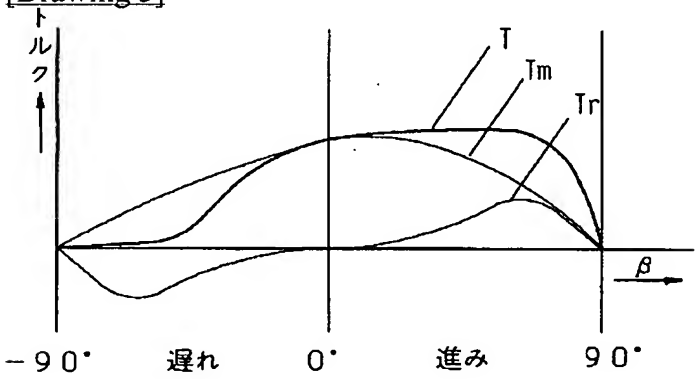
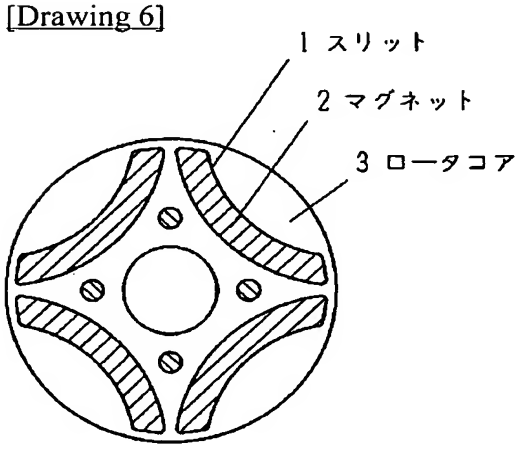


T 総合トルク
Tr リラクタンストルク
Tm マグネットトルク

[Drawing 6]



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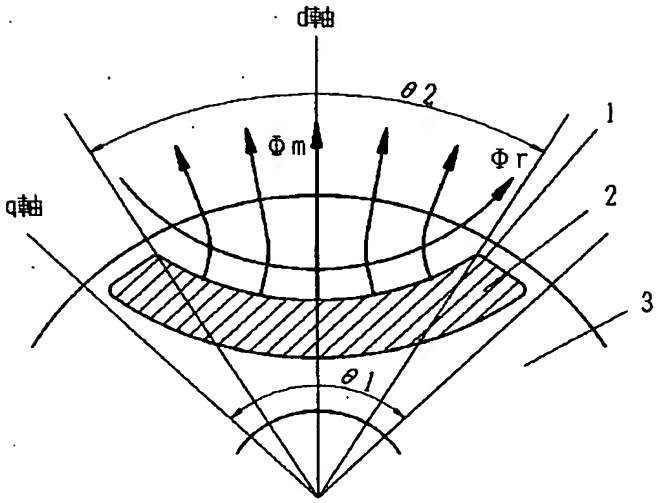
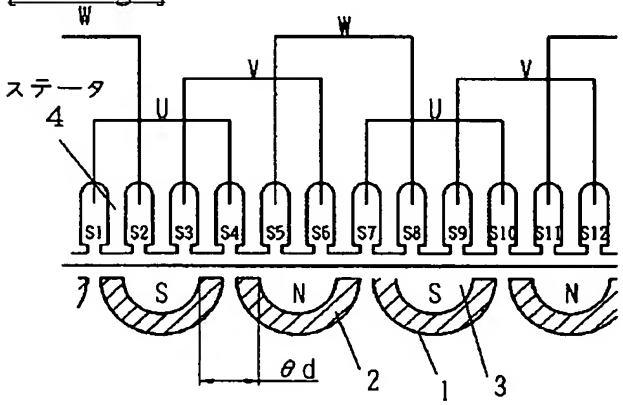


[Drawing 8]



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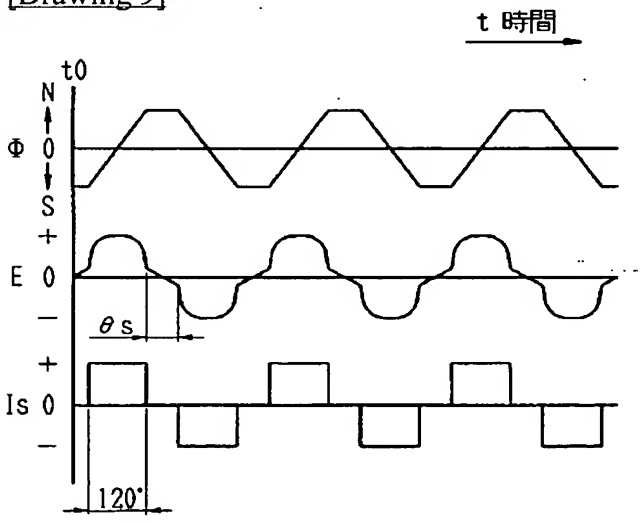
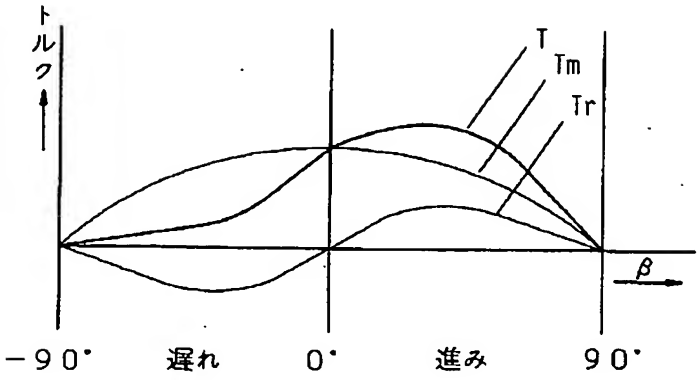


[Drawing 10]



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